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ABSTRACT

From a system dynamics perspective, distinctions between organizations and their environments are not objective givens, but hypothetical formulations. Wherever a reciprocal effect of variables is hypothesized, these variables are considered to be inside a single problem system. Everything outside this model system is the environment. To understand, for example, the problem of the shortage of math and science teachers, it is necessary to consider the relations between two sectors--the educational and the industrial--that have been traditionally viewed as "environmental" to each other, but which can be seen from a system dynamics perspective as integral parts of a single functional system. As a series of causal-loop diagrams illustrates, the dynamics of industrial salaries and technical education may be viewed as constituting such a system. In times of a shortage of highly trained technical personnel, rising industrial salaries tend to draw personnel away from teaching positions, thereby weakening the quality of math and science programs and undermining the pool of technical personnel for both schools and industry in the future. It is important to understand such relations as constituting a single problem system so that policy options may be aimed at defining interventions within that internal system that will be effective under a variety of environmental conditions. (JBM)

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ORGANIZATIONS AND THEIR ENVIRONMENTS:
A SYSTEM DYNAMICS PERSPECTIVE

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Boston University

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How is the world of logic which eschews
"circular argument," related to a world
in which circular trains of causation
are the rule rather than the exception?
(Bateson, 1979, p. 20)

The Distinction between
Organization and Environment

Clearly, the transcendent emphasis in traditional treatises on organizational life has been on bureaucratic structural variables and human relations. In the past decade or so, there has emerged also a growing concern for environmental variables and the relationship between "organizations" and their "environments."

In our view, this more recent literature represents a significant advance in the formulation of a conceptual framework to address important organizational policy issues. However, it still tends to treat organizations and their environments fundamentally as if they were clearly definable entities and clearly distinguishable from one another practically and conceptually. It is our position that organizational boundaries are, in practice, essentially impossible to define in absolute, objective terms and that what is important in practice is to focus analytic attention on what may be called "problem systems."

This position represents a contingency approach to conceptualization. It recognizes that the fundamental purpose in defining analytically a bounded entity called an organization and differentiating it conceptually from its "environment" is to create a problem system and a policy object. This entity is a problem system in the sense that it represents a closed-bounded system of variables which are thought to be capable of generating the problem. It is a policy object because it will be used to imagine how different interventions (i.e., "policies") may interact with its natural dynamics to ameliorate certain perceived "problems," and, ultimately, it will be the target for selected policy interventions.

From this contingency perspective, an organization is not perceived as an objective given but rather as a hypothetical system, with sufficient simplicity to expedite analysis, but also with sufficient logical connection to the infinite complexity of the real world to make the analysis plausible. Thus, the distinctions between organizations and their environments are essentially theoretical distinctions. The particular formulation of these distinctions and the definition of the problem system depends on how one defines the problem.

The Problem System: Perspective and Method

The System Dynamics approach [1] is to seek to define a problem based on available information about historical and projected trends of problem indicators. Problems are perceived in terms of behavioral discrepancies between desired and observed indicator trends. Desired trends are assumed to be value-based, whether the relevant values are made explicit or not. What is defined as problematic is clearly constituency referenced, where a constituency is defined in terms of at least relative value homogeneity. Observed trends are data-based, where data are defined quantitatively or as quantitative transformations of qualitative data. [2]

Projected trends represent hypotheses about the future. They constitute transformations of one kind or another of historical data. They always imply theories of relationship between the past and the future. Such theories may describe explicitly structural relationships and scenarios or they may implicitly assume that whatever dynamics generated observed historical trends will persist unchanged and will generate similar, often linear projections into the future. [3]

In formulating problem systems, system dynamicists hypothesize causal structures, or models, which can explain historical trends, which establish a basis for predicting the future behavior of problem indicators, and which, after appropriate logical analyses, provide a conceptual framework for imagining potentially useful policy interventions and for testing the effects of such interventions systematically within the theoretical framework of the models. These models are conceived of as closed-rounded systems in that the variables which comprise a particular model are causally connected in circular fashion. This implies that in some manner each variable is affected by changes in every other variable in the model.

The environment is defined, in undifferentiated fashion, as everything which is not explicitly inside the model. Changes in the environment may affect variables within the model but the impact of the

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- [1] For more information on System Dynamics, see Forrester (1968), Richardson and Pugh (1981), and Roberts, et al. (1983).
 - [2] We would argue epistemologically that differences between "quantitative" and "qualitative" data are of degree, not of kind. We would also take the position that even seemingly hard, quantitative data have a subjective dimension which references the underlying values and perspectives that guided their definition, collection, and interpretation.
 - [3] System dynamicists tend to view such assumptions with suspicion. History and science are replete with examples of non-linear trends and effects (e.g., population growth, technological and industrial growth, and, possibly, the atmospheric "greenhouse" effect). These include examples of threshold effects (e.g., "takeoff" points and freezing points).

model on the environment, if any, is unrecorded and unanalyzed. One assumes that the impact of the problem system on the environment is not a matter of concern.

It is important to note that wherever a variable is hypothesized to affect and be affected by one or more variables in the model, that variable, ipso facto, has been defined as being inside the problem system (i.e., inside the model). This principle essentially defines, from a system dynamics perspective, the relationship between the problem system and its environment.

Tests of the construct validity of the model include detailed examinations of the logical correspondence between dyadic causal relationships hypothesized in the models and the best information available in the world of empirical reality. Such information includes experimental studies and theoretical writings as well as observed behaviors and oral reports by actors who are knowledgeable about the workings of relevant social systems. Other tests are accomplished by translating the causal structure into a set of mathematical equations for computer simulation modeling. Simulation modeling allows one to test the robustness of the causal theory under a wide range of conditions, to assess the theory's internal consistency, and to ascertain whether the theory is really capable of generating the observed problem discrepancies.

Models are often formulated interactively. That is, models based on written and oral information are often examined by knowledgeable respondents and refined on the basis of further information provided by them in response to examining and discussing the assumptions built into the models. This methodological approach is analogous to the process used by police artists in building and refining their composite sketches.

An Illustrative Example: The Shortage of Math and Science Teachers

Variables included in these problem systems often include some that might normally be thought of as organizational variables and others that might normally be thought of as environmental variables. For example, to appreciate the essential crisis of math and science education in the United States at the present time, a crisis marked by dramatic shortages of highly trained math and science professionals and by equally dramatic shortages of the qualified math and science teachers needed to correct this shortage, it is necessary to describe a problem system which elucidates two sectors which are at once highly interdependent and also in a potentially damaging competition for resources and key personnel.

To understand the policy implications of this problem it is necessary, we would argue, to attend systematically to a series of complex relations between two sectors. One is an educational sector, comprised of elementary schools, secondary schools, and universities. The second is an industrial sector, within which particular emphasis needs to be placed on its high technology sub-sector. Relations between these sectors appear to be generating a dysfunctional and potentially

dangerous set of dynamics.

What is important in this model for the present discussion is that it turns out to be difficult to distinguish between "organizational" and "environmental" variables. The point here is twofold: (1) each of the sectors, within itself, is comprised of multiple "organizations" in a complex environment (Emery and Trist, 1965) and (2) each sector can be viewed as a significant portion of the environment of the other.

On the one hand, the educational sector provides trained personnel for the industrial sector, which is dependent on it in this respect. On the other hand, the industrial sector provides jobs for graduates of the educational sector and in this way constitutes a major determinant of demand for particular courses of study. Thus, the two sectors, which might traditionally be viewed as two independent organizational entities, each "environmental" to the other, can be seen from a different perspective to be integral parts of a single functional system. The focus in this analysis is particularly on the high technology component of industry and the technical education component of the educational sector (i.e., that is on that component which is centered on mathematics and science as its focal disciplines).

The Blackboard Goose and the Silicon Egg

This is the story of a coming American tragedy. Clearly, another tragedy is not what the United States needs right now. However, it turns out in this story that the Blackboard Goose which has produced the Silicon Egg is being done in by its own offspring.

There is a substantial and growing shortage in this country of qualified elementary and secondary math and science teachers. The long term implications of this trend for U.S. industry are grim. This seems especially true for the high technology sector, which has been seen by most analysts as the nation's economic bellwether into the future. The following analysis is put forth in defense of this projection, which may seem unduly dour at a time of continuing high profits in "high tech."

The Problem

The essentials of the problem can be seen in the following tables (Tables 1 and 2) published by the American Association of Colleges for Teacher Education (April, 1982). These figures underscore the extent of the presence in the nation's classrooms of unqualified math and science teachers.

<u>Census Region</u>	<u>1980-1981</u>	<u>1982-1983</u>
Pacific States	75%	84%
Mountain States	44	43
West North Central States	26	43
West South Central States	63	63
East North Central States	23	32
East South Central States	43	40
Northeastern States	11	9
Middle Atlantic States	40	46
South Atlantic States	48	50
NATIONWIDE	45%	50%

Table 1. Percentage of Newly-Employed, But Unqualified Science and Math Teachers. (Courtesy National Science Teachers Association) [AACTE, 1982, p. 2]

Despite shortages of math and science teachers in the nation's elementary and secondary schools, shortages which have become increasingly serious during the last decade, colleges of education have experienced progressively low enrollments in programs of study leading to certification of math and science teachers. The deleterious effects of this trend are compounded by the fact that there has also been, during the same period of time, declines in the proportion of math and science education graduates who actually enter teaching (see Table 2).

	<u>Graduating Teachers</u>		<u>% Entering Teaching</u>	
	<u>Science</u>	<u>Math</u>	<u>Science</u>	<u>Math</u>
1971	100	100	59	63
1972	90	91	58	68
1973	85	86	58	64
1974	75	73	55	65
1975	65	60	56	62
1976	65	45	59	61
1977	55	36	56	63
1978	50	27	52	59
1979	40	27	54	60
1980	35	23	54	55

Table 2. Science/Math Teacher Supply Data 1971-1980 (Values Represent Percentages Indexed to 1971, Courtesy National Science Teachers Association) [AACTE, 1982, p. 6]

The trends suggest that despite a growing need for math and science teachers in the elementary and secondary schools, (1) talented students are not preparing in sufficient numbers for math/science teaching and (2) even among those who are so prepared, many take positions outside of elementary and secondary school teaching. The reason for this, we suggest, lies in the economic distinction between "need" and "demand." There is a pressing need for qualified math and science teachers; there is, however, under current structural conditions, little demand in the economic marketplace, as represented by the salary structure of the schoolhouse, for personnel trained in math and science.

The Problem System

Structurally, the dynamics of the problem seem relatively straightforward, despite the complexity of its phenomenology. Essentially, there appear to be two control mechanisms which are working against one another and a third control mechanism that is not working at all. These control mechanisms work to determine the supply of highly trained technical personnel and to regulate the flow into industry and schools of these personnel. Two of these control mechanisms are short-range (0-3 years); the other is long-range (4-16 years).

The short-range control mechanisms relate salaries to the demand/supply ratio of highly trained technical personnel. One is located in the industrial sector, the other in the educational sector. The long-range control mechanism is situated in the educational sector, relating the training of technical personnel to the needs of the industrial sector. Our central hypothesis is that under conditions of sharply accelerating demand in the industrial sector, the short-range control mechanism around salaries in industry so dominates the total personnel system that it can erode the long-term capacity of the educational system to replenish the supply of highly trained technical personnel. We believe that current trends marking a shortage of both advanced technical personnel in industry and math/science teachers in schools are symptomatic of this underlying dynamic. It is our position that the short-term appetite of the high technology industries (i.e., the Silicon Egg) for trained personnel is eating away at the human capital of the educational sector (i.e., the Blackboard Goose) on which it ultimately depends for its future supply of these personnel. Furthermore, we believe that this possibility becomes increasingly prominent as the proportion of the Gross National Product (GNP) devoted to education approaches some cultural (if as yet undetermined) limits.

The next sections of the paper are devoted to describing the overall structure of this high technology educational-industrial personnel system. The general plan is to provide a broad overview of the system as it has operated historically, followed by more detailed descriptions of the industrial and educational sectors. These will be depicted in sufficient detail to illustrate the essential dynamics of the problem system.

Again, it is important to observe how each sector is structurally a part of the other's environment. What can be seen is an organization of

elements in a problem system which is characterized by what might be called, "reciprocal environmentality." It is our view that this kind of structure is a common occurrence in problem systems and that its recognition by students of organization, traditionally wedded to sharper distinctions between "organization" and "environment," is a useful theoretical advance.

The point of the concept of reciprocal environmentality is that wherever two organizations, or sectors, are so related to one another, they are not environments at all, in any functional useful sense of the term. The fact that each is a significant environment of the other implies that they constitute a single functional system. The policy implication is that the most useful analytic perspective will be achieved when the two organizations or sectors are treated analytically as a single policy object, i.e., as a unified problem system.

An Overview of the High Technology Personnel Supply System. A basic force driving industrial development in the U.S. has been its relationship with technology (i.e., invention) and scientific education. Essentially these have operated to reinforce one another over time in what systems analysts call a "positive feedback loop" (see Fig. 1).

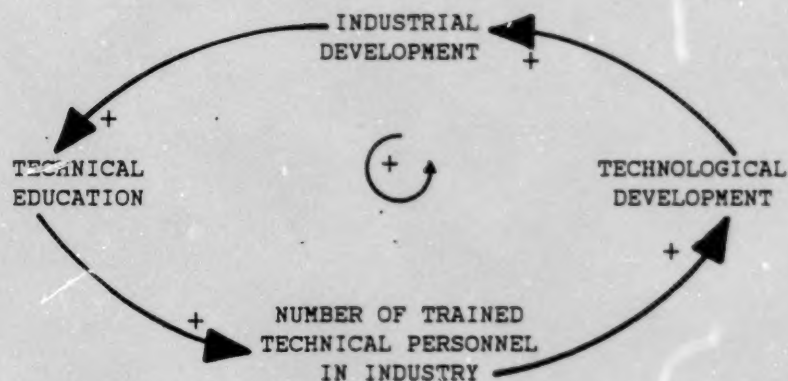


Fig. 1. Self-Reinforcing Dynamic Among Industrial Development, Technical Education, and Technological Development. [4]

- [4] In these causal-loop diagrams, the plus and minus signs on the links between variables indicate the nature of the relationship (i.e., direct or inverse). For example, in this figure, a plus sign between Industrial Development and Technical Education means that as industrial development increases, technical education will also increase and as industrial development decreases, technical education decreases. The minus sign (see Fig. 2) between Number of Trained Technical Personnel and Discrepancy in Technical Personnel means that as the number of trained technical personnel increases,

The diagram (Fig. 1) depicts a highly aggregate set of relationships which have been operating historically in the United States (and in other countries of the world). According to this model, industrial development fosters technical education. Indeed, in U.S. educational literature, there is ample evidence of the ideological connection between business and schooling. Major efforts following the Soviet launching of Sputnik to re-conceptualize and re-fund science and mathematics education illustrate the close connection in the American mentality of technical education and the technological success of the nation. Current concerns, especially by the high tech industry, for math and science education further underscore this connection. It is the extent and quality of technical education in the country which determines the number of trained technical personnel available to U.S. science and industry, and which, in the long run, determines the state of the nation's technological development. Technological development, in turn, is the foundation on which depends the future of industrial development. Thus, the circle of causality closes upon itself.

Implied in this description of the interaction between technological development and technical education is the existence of a control mechanism which operates to raise the level of technical education and technological development when a discrepancy exists between the current number of trained technical personnel and the number required by the level of industrial development. This additional piece of structure is diagrammed in Fig. 2 and represents the long-range control mechanism we mentioned earlier.

This diagram illustrates the operation of a negative control structure which, in the fashion of a thermostat mechanism, adjusts technical education quantitatively to the demand in industry for trained technical personnel. Thus, in a manner to be illustrated in more detail later, forces in the society work to compensate for shortages (or oversupplies) which develop for technical personnel through industrial development (and to close down the flow of additional trained technical personnel when they are not needed).

For example, the availability of jobs and opportunities for higher salaries attracts students to training programs, which open up to meet the demand (e.g., computer training programs over the past several years). Similarly, in inverse fashion, lack of job opportunities discourages trainees and leads to a reduction in the number and capacity of training programs (e.g., teacher training programs in the last decade). Of course, as the reader will already have noted, these dynamics do not operate instantaneously. There are delays in the individual and institutional response mechanisms and it can take up to sixteen years or more to train a competent technical person.

the discrepancy in technical personnel decreases and as the number of trained technical personnel decreases, the discrepancy in technical personnel increases (assuming continued growth in the need for technical personnel in industry). The arrowheads on the links between variables indicate the direction of causation.

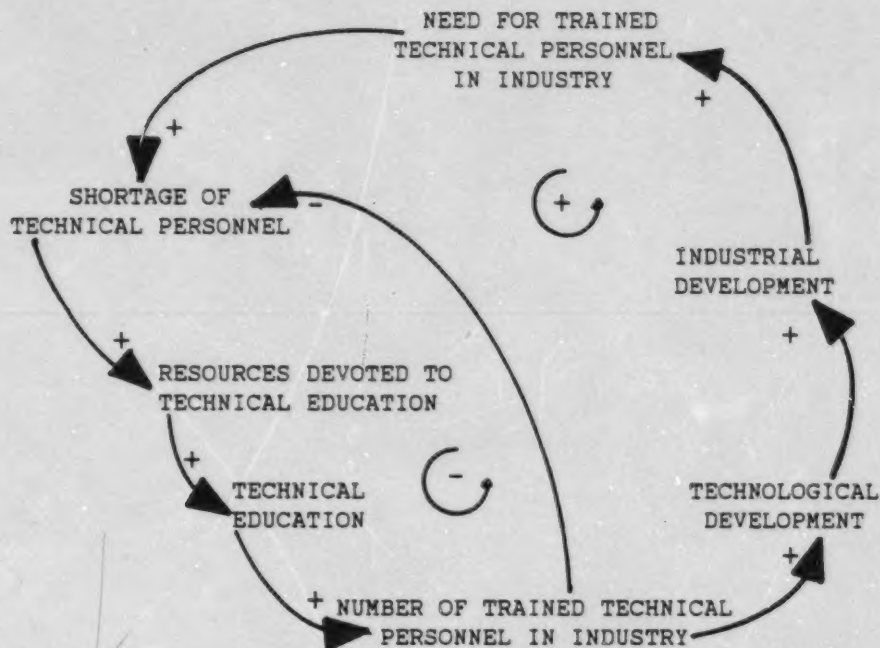


Fig. 2. Added Negative Control Loop Maintaining the Flow of Trained Technical Personnel.

The Industrial Sector. As suggested earlier, an important source of pressure on the educational system derives from its competition with the industrial sector for qualified personnel, especially in the technical fields. In order to understand the dynamics of this competition, it is necessary to describe the dynamics of each of the two sectors, industrial and educational, and of the interaction between them. We will describe in several diagrams of increasing complexity the dynamics of the industrial sector with respect to the flow of trained technical personnel and then do the same with the technical educational sector. Finally, we will discuss the interactive dynamics of the two sectors.

Figure 3 illustrates both the self-reinforcing loop around technology and salaries in industry and the negative control loop which represents the short-range control mechanism by which salaries control the flow of technical personnel to industry consistent with need. It also depicts the dependency of industry for trained technical personnel on the total number of trained technical personnel available. This variable is shown as exogenous in this partial model but it will ultimately be shown to be dependent on the productivity of the technical education sub-sector of the education sector.

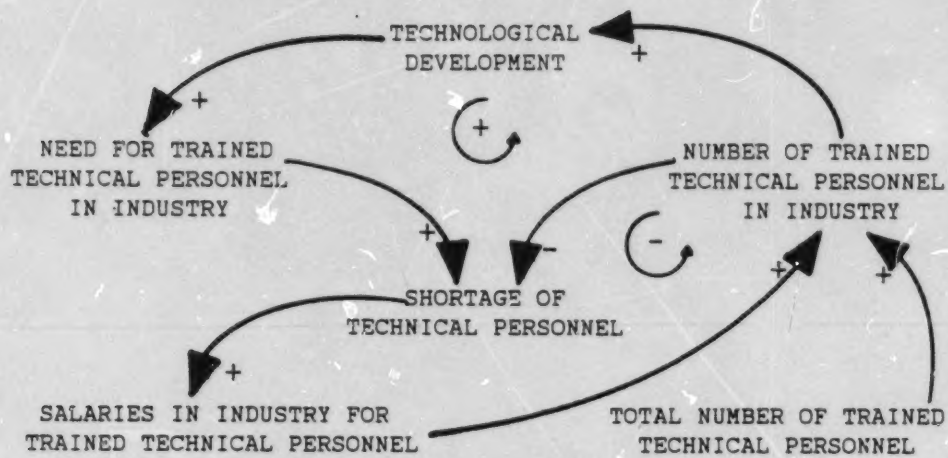


Fig. 3. Self-Reinforcing Loop Between Technology and Industrial Salaries for Trained Technical Personnel.

Figure 4 illustrates the additional role of profits in this system. This portion of the model describes an important dynamic that reinforces the ability of the industrial sector to compete effectively with other social sectors for highly trained technical personnel. The industrial sector is profit-based. As technology improves, industry capitalizes in the world markets to improve its profit margins. In fact, a crucial danger inherent in the problem system is that the interaction between the industrial and educational sectors will lead ultimately to a significant decline in comparative U.S. technology and to a decline in the profit-generating capacity of U.S. industry (already in a technology squeeze in some of its sub-sectors).

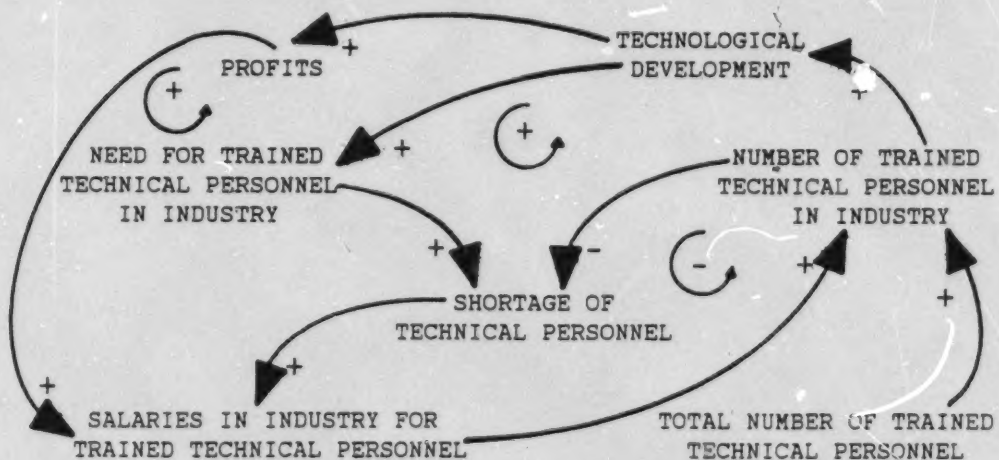


Fig. 4. Additional Self-Reinforcing Loop through Profits and Industrial Salaries for Trained Technical Personnel.

The Educational Sector. The problem with profits, which most perceive as fundamentally healthy to achieve, is that they enhance the ability of industry to pay high salaries, especially under conditions of shortage in highly trained technical personnel. They exacerbate the draining of math/science talent from schools where they are needed to supply future technically trained personnel for all institutions of society.

The difficulty, however, is not necessarily that profits contribute to the salary control capability of the industrial sector but rather that the comparable control mechanism in the educational sector is diffuse and it has also been weakened by the cumulative effects of powerful historical trends.

It is diffuse in that the salaries of math and science teachers, which compete directly with industrial salaries for technical personnel, are responsive to market forces only as part of a uniform salary structure in which they are aggregated with other, non-technically trained teachers.

It has been further weakened, we propose, by the emergence of important dynamics which were relatively latent in earlier times. As a variety of forces, including historical industrial development, have escalated the level of formal schooling in the United States, two factors seem to be working to limit the ability of the educational sector to respond currently to its need for more highly trained technical personnel.

One of these has to do with the increasing cost of education as a proportion of the GNP, largely due to two factors: (1) the self-reinforcing demands for equality of educational opportunity across socio-economic, ethnic, and ability groups (Weaver, 1982) and (2) economic stagnation, partly affected (now and in the future) by the ability of the society to renew its educational capacity.

The other limiting factor, we hypothesize, may be associated with some natural limits in the general population, given the current state of the art in the biological and pedagogical sciences, on the proportion of students with prerequisite innate ability for advanced technical training. Exponential growth in the demand for technically trained personnel may soon begin to test these limits.

The structural dynamics of the educational sector are illustrated in the next two diagrams. The first of these (Fig. 5) describes the basic sector structure. This structure is comprised of three feedback loops.

The first of these (Loop 1) depicts an important self-reinforcing set of interrelationships among five factors. It will be noted here that the quality and capacity of math and science programs, which determine the number of students in training, is dependent on an adequate supply of qualified teachers. This, of course, is at the heart

of the problem the model is designed to address. Thus, since the schools prepare virtually all technical personnel (in-migration excluded), including its own supply of future teachers, present shortages of teachers help lead to future shortages, as well. Thus, this positive feedback loop is characterized by what has been called "vicious cycle" behavior. This is crucial because as trained technical personnel, in limited supply, are siphoned away from teaching by relatively high industrial salaries, the consequent shortage of qualified math and science teachers works to reduce the quality of programs and, thereby, the number of trained personnel available. This tends to further reduce the supply of qualified teachers and fuel a vicious downward spiral.

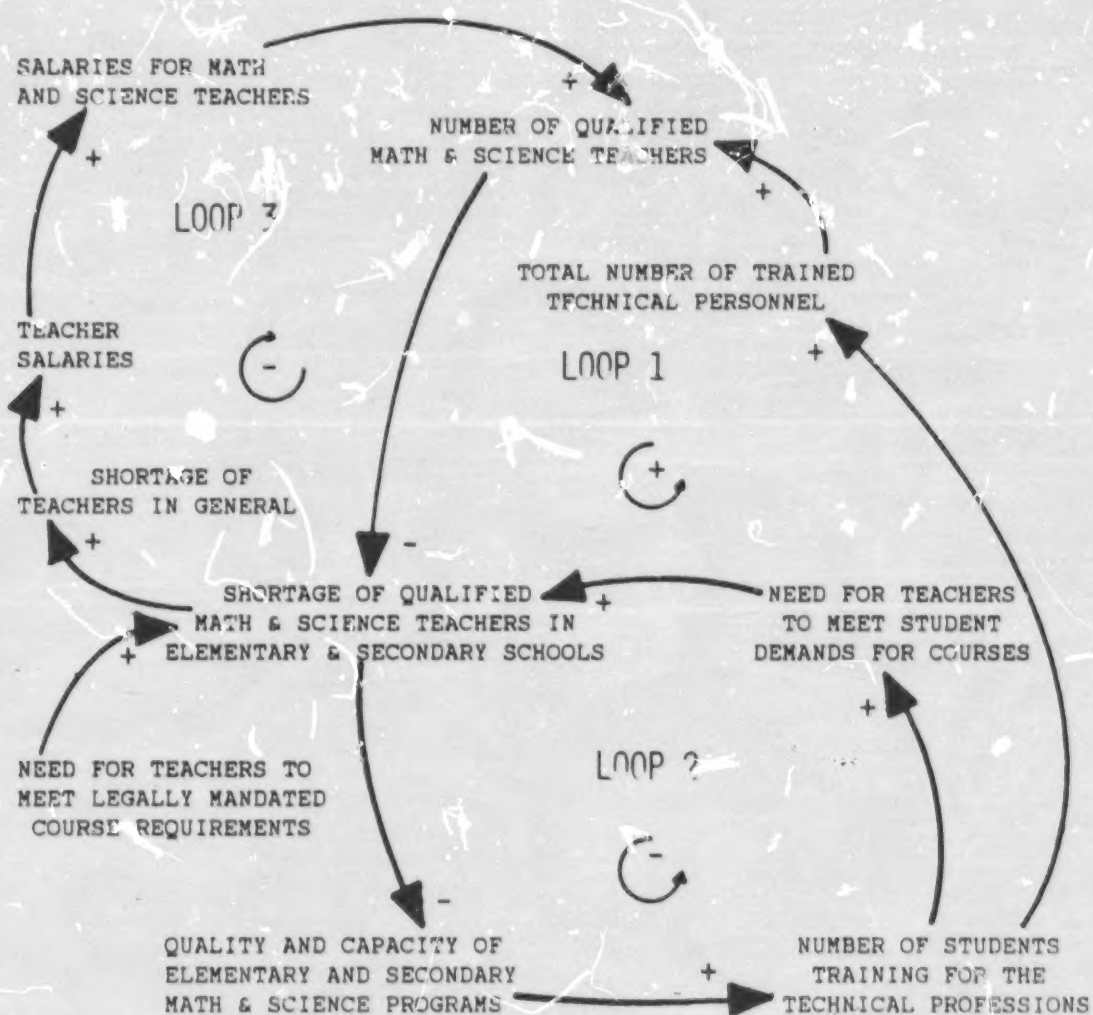


Fig. 5. The Technical Education Sector: Basic Structure

Two negative control loops also play a part in the technical education sector. One tends to limit the number of students based on the number of qualified teachers (because of reduced numbers and quality of math and science programs). It also works to reduce the number of teachers, if necessary, consistent with the number of students enrolling in math and science courses (Loop 2).

The remaining loop is also negative. It brings pressure on salaries consistent with the supply of and the demand for teachers. But, as noted earlier, salaries, by historical policy in the U.S., are almost everywhere uniform for all teachers. Thus, the salary control mechanism (Loop 3) is responsive to the general supply and demand condition, not the specific condition with respect to math and science teachers, alone (nor, even more particularly, to sub-specialities of math and science teachers).

Figure 6 adds to the basic structure two negative feedback loops which represent emerging limits on the technical educational sector. One of these (shown as Loop 4 in this diagram) retards the growth in teacher salaries as educational expenditures in general approach some hypothesized (but as yet not clearly established) limiting proportion of the GNP. This was briefly alluded to earlier.

What is represented implicitly is the contest for resources among powerful competing sectors: e.g., education, health, welfare, and the military. It represents what we believe to be the reasonable idea that educational expenditures cannot continue to grow indefinitely proportionate to the GNP. We believe that current cost caps in education (and cost containment measures in the health sector, as well) are indicative of the reality of these limits to growth.

The important point here is that this control structure, which has become particularly salient in this decade, further and significantly limits the elasticity of math and science teacher salaries, especially to the extent that they are tied to teacher salaries more generally.

A second natural control structure (shown as Loop 5 in Fig. 6) represents what we presume to be the natural limits of the talent pool. As the technical education sub-sector seeks to train higher proportions of the total population of students in math and science related fields, we hypothesize a kind of depletion effect similar in effect to the law of diminishing returns found in the mining of non-renewable resources.

As extraction proceeds over time, the mined ore is generally of poorer quality and more expensive to extract. The hypothesis here is that as a greater proportion of students is trained for professional work in technical fields, the marginal student will be poorer and more difficult, perhaps more costly, to educate. Thus, it seems, there are limits to the numbers of quality technical personnel who can be efficiently trained.

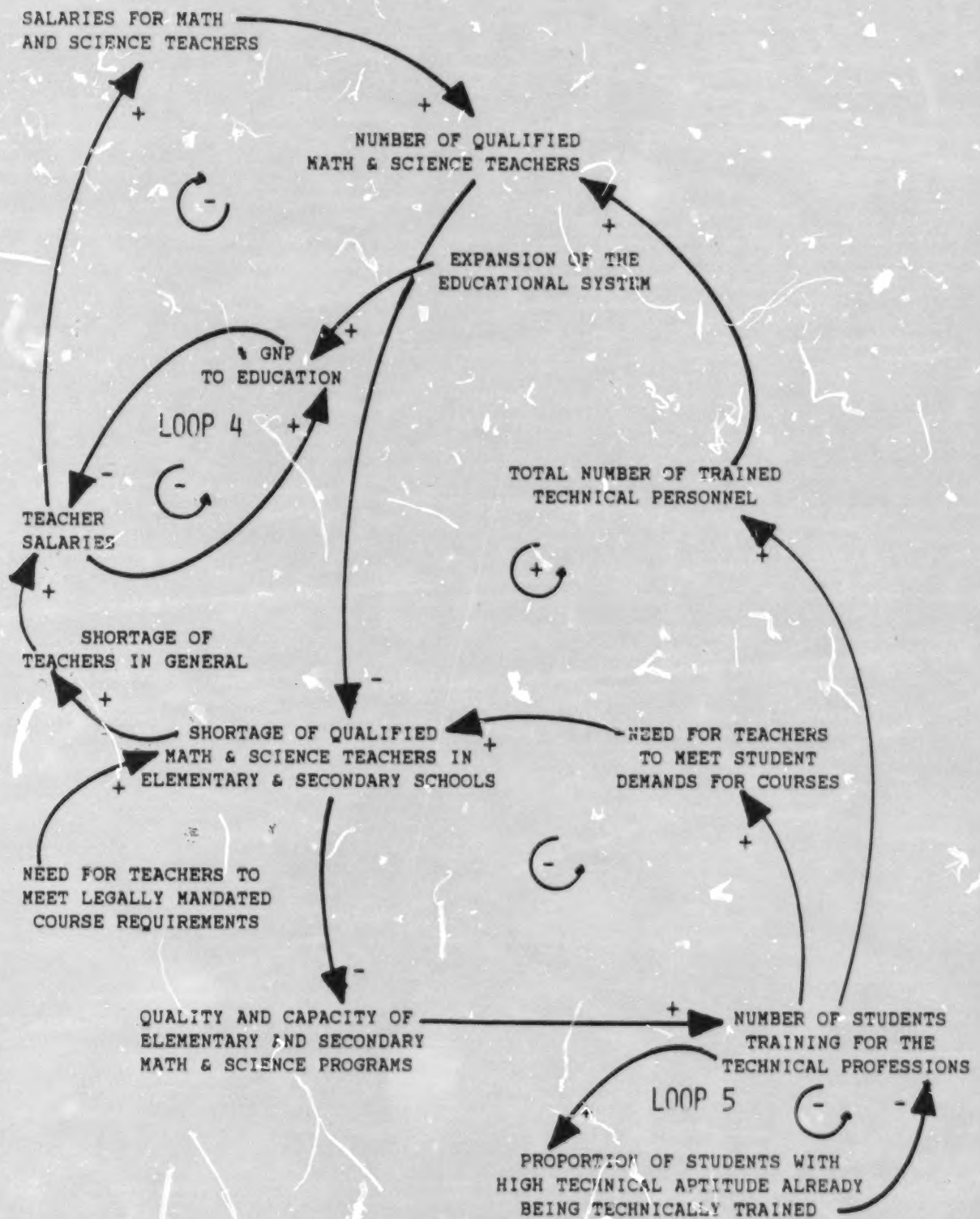


Fig. 6. The Technical Education Sector

The full model is displayed in the final figure (Fig. 7). In this diagram, the effects and counter-effects of the industrial salary dynamic on technical education are made explicit. In times of shortage of highly trained technical personnel, the very times technical education becomes most important to meet this shortage, rising industrial salaries begin to exert strong pressure on the most qualified school personnel to transfer from teaching positions to positions in the industrial sector. This dynamic operates both to drain experienced teachers from the schools and to draw off the best potential talent among high school and college graduates from the teaching pool. The effect over time is to weaken the quality of math and science programs, thus further undermining the pool of technical personnel for schools and industry into the future. The long-term dangers of this dynamic, it seems, would be difficult to overstate.

Policy Implications. It is not the purpose of this paper to explicate a detailed analysis of policy options. This will be pursued elsewhere. However, two avenues of exploration seem reasonably evident from the structure of the problem system presented above. One broad policy option is to examine policies to uncouple currently uniform teacher salaries and to restore economic elasticity to teacher salaries by grade level and/or across subject disciplines. This policy would have the structural effect of coupling math and science salaries directly to the supply/need ratio of math and science teachers, thus constituting a salary control structure competitive with industry. [5]

A corollary policy which recommends itself is somehow to connect high technology profits to the support of the math and science programs upon which they depend in the long term. This envisions the creation of an appropriate structure to accomplish this through contributions to schools by high profit, high technology firms of materials, equipment, and personnel to support science and mathematics programs.

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- [5] We are not unaware of the political complexities of implementing such a policy. However, two ideas seem relevant in this regard. One is that it is our purpose in this paper to show the dynamic effects of the current structure. It seems important in our view, given not only the short- but the long-term dysfunctions of this structure, to make as clear as we can from a policy perspective the costs associated with the continuation of the present system, for whatever reasons. The other is that the implementation issue illustrates engagingly the epistemological dilemma of the policy analyst: i.e., recommendations to remediate a problem in one system level are always implemented at another, higher system level. Thus, there is always one more system to be analyzed.

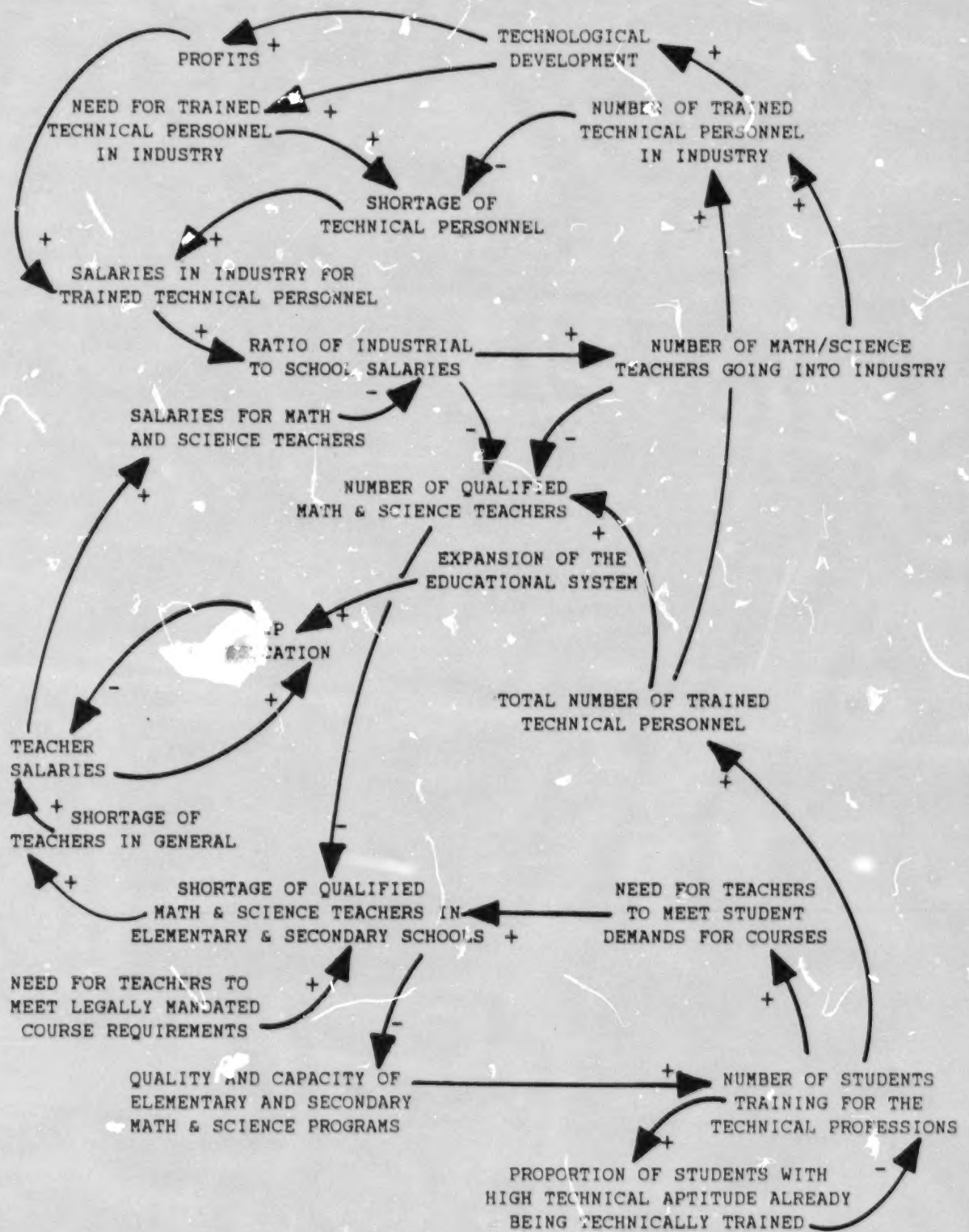


Fig. 7. The High Technology Educational-Industrial Personnel System.

Such a policy, if effective, can operate to counter the negative effects of high technology salaries in draining qualified technical personnel from the schools. This policy might be especially effective if combined with modifications in regulations and hiring practices to permit and encourage the joint employment of qualified personnel by industry and schools. It might also include structural arrangements by industry to help upgrade the skills of present science and math teachers and to help provide training and apprenticeships to promising secondary school students. Structurally, this policy connects the quality of educational programs directly to industrial profits, thus offsetting, at least to some extent, the eroding effects of industrial profits on schools through the salary cycle. Based on what, at this time, is a preliminary policy analysis without computer modeling, this approach, we feel, does hold some promise of attractiveness to the high tech industry. The major firms in particular would seem to have much at stake.

Conclusions

The example of a policy analysis focusing on the current shortage of math and science teachers was presented to illustrate an alternative perspective to the traditional one on the relationship between "organizations" and their "environments." The example was presented from the perspective of System Dynamics to suggest that it may be useful to consider the distinctions between these two concepts as more relative and less absolute than they have traditionally been considered.

Whereas in traditional analysis the boundaries separating organization and its environment have been viewed as clearly definable, at least theoretically, the system dynamics perspective is to define a problem system which often includes elements from multiple organizations and institutional sectors. It is not unusual in such problem systems, as in the example given, for organizations which, more traditionally, might be viewed as mutually environmental (thus, conceptually distinct from one another) to be recognized as dynamically interrelated in the problem system.

The focus, then, for the system dynamicist, is on understanding the problem system as an "internal structure" (in a sense as a macro-organization) and on defining interventions within that internal system that will be effective under a variety of environmental conditions. This, it seems to us, is the essence of the system dynamics perspective on policy analysis and on the relationship between organizations and their environments. It is to define the significant parts of the environment on the inside, not on the outside.

REFERENCES

American Association of Colleges for Teacher Education. AACTE briefs, 1(4), April, 1982.

Bateson, G. Mind and nature: A necessary unity. New York: E. P. Dutton, 1979.

Emery, F. E., and Trist, E. L. The causal texture of organizational environments. Human Relations, 18, February 1965, pp. 21-32.

Forrester, J. W. Principles of systems. Cambridge, MA: MIT Press, 1968.

Richardson, G. P., and Pugh, A. L., III. Introduction to system dynamics modelling with DYNAMO. Cambridge, MA: MIT Press, 1981.

Roberts, N., et al. Introduction to computer simulation: The system dynamics approach. Reading, MA: Addison-Wesley, 1983.

Weaver, W. T., The contest for educational resources: Equity and reform in a meritocratic society. Lexington, MA: Lexington Books, D.C. Heath and Company, 1982.